MEchanical Diode Resonant Rectifying Actuator (MEDIRRA)

Presented by:

George A. Lesieutre

Penn State University

DARPA CHAP Kickoff

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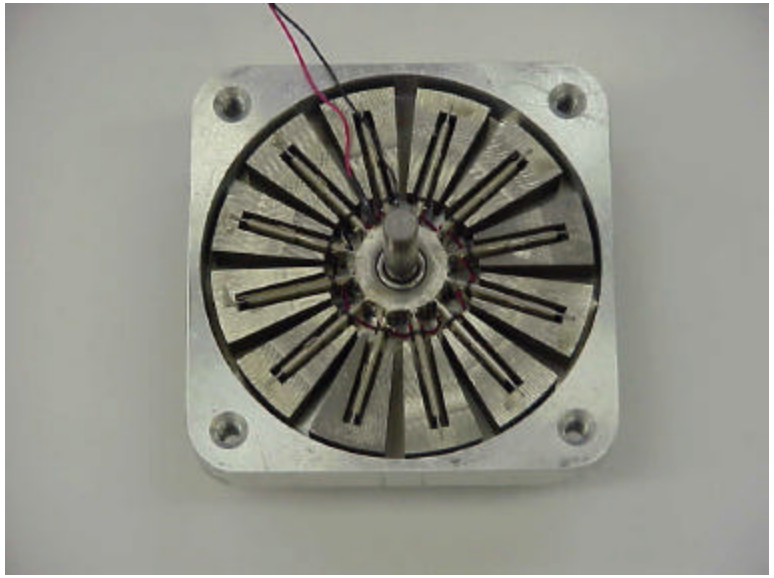
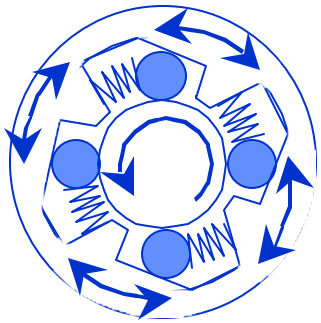
MEDIRRA Overview

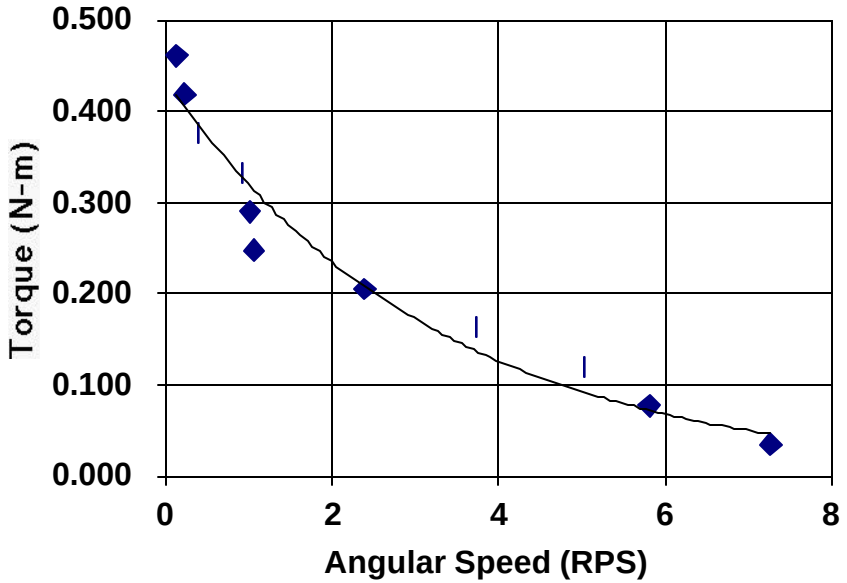
- Phase II Objective
  - Piezoelectric actuator with power density and efficiency that exceeds current EM technology
  - Enable agile high speed missile mission
- Phase I Scope
  - Actuator / Motor Requirements
    - Missile application, commercial manufacturing
  - High-Power Motor and Electronics
    - Concepts, modeling, mech. diodes (reverse, linear)
    - Regenerative power electronics
  - Motor Fabrication, Testing, Assessment

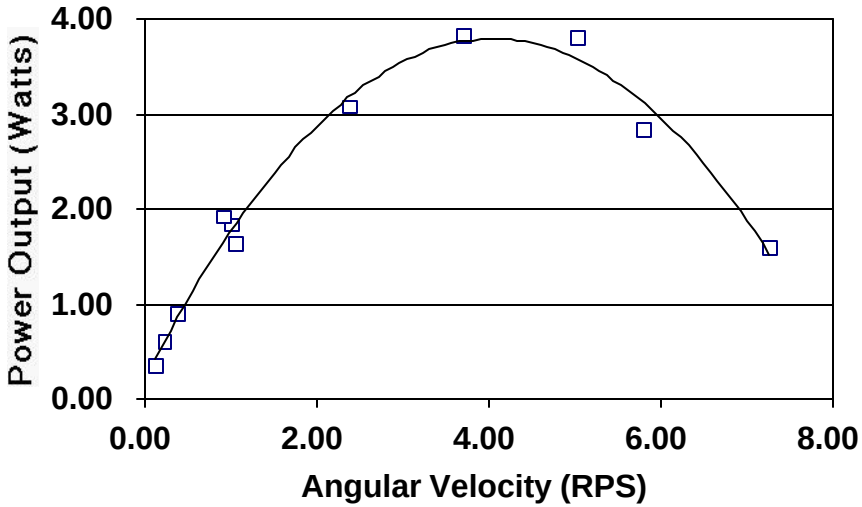
Builds on DARPA SAMPSON Technology



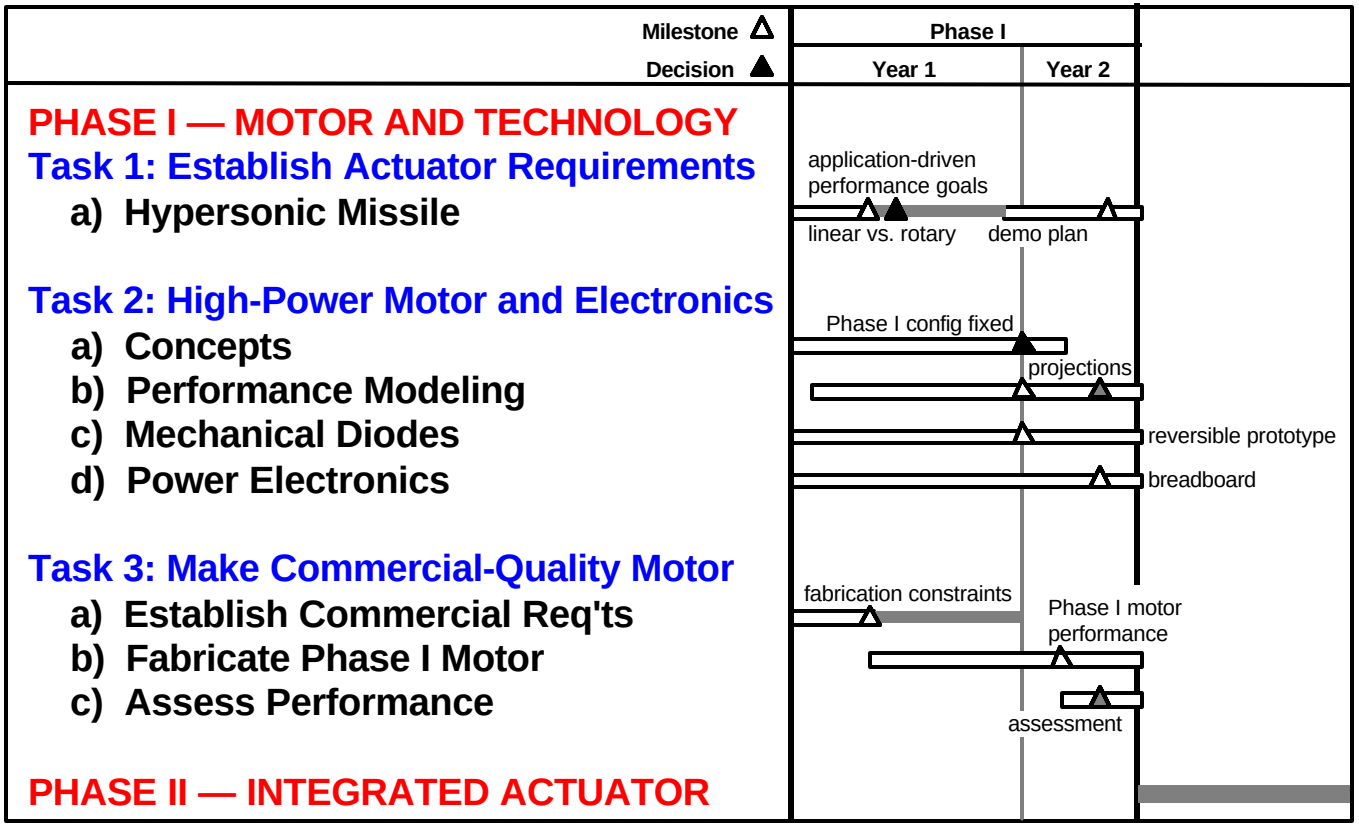


Rotary Mechanical Diode





MEDIRRA Schedule



MEDIRRA Team

- **Penn State** (Center for Acoustics and Vibration)
  - Piezoelectric motor technology, mechanical diodes
  - Gary Koopmann, Eric Mockensturm
- **Virginia Tech** (Center for Power Electronics Systems)
  - Efficient regenerative drive electronics
  - Doug Lindner
- **Boeing Phantom Works** (St. Louis)
  - Aerospace (missile) applications; (DARPA SAMPSON lead)
  - Ed White
- **MPC Products Corp.**
  - Aerospace actuator supplier; (AW&ST 1999 Tech. Innovation)
  - Darrin Kopala
- **Torrington** (mechanical diode technology)

Progress

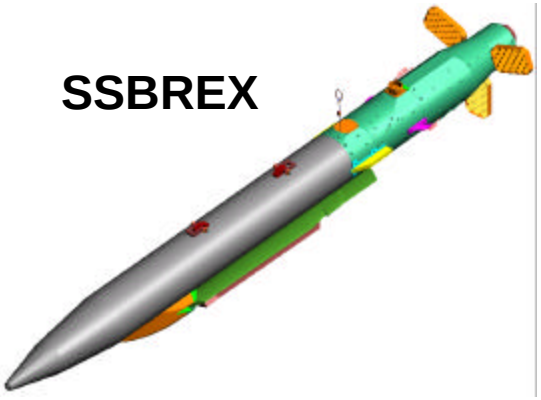
- **Expect to be under contract 1 JUL 2000**
  - **Army Research Office**
  - **Technical Monitor: Dr. Gary Anderson**

Technology Transition

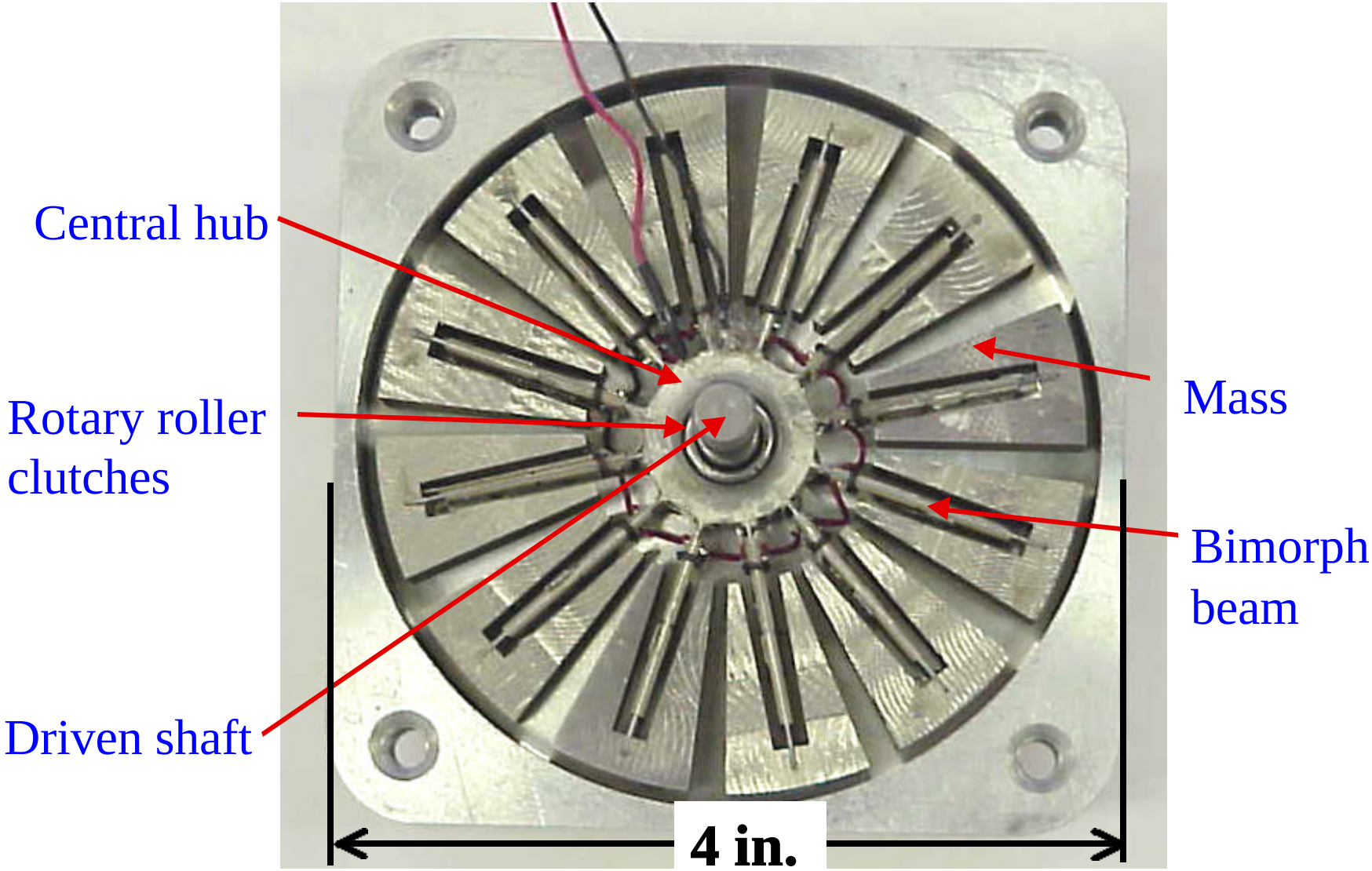
- **MPC Products Corp.**
  - **Aerospace actuators**
  - **Many potential customers**

- **Boeing Phantom Works (St. Louis)**
  - **Aerospace applications**
  - **Transition integrated smart structures to Boeing products**

SSBREX

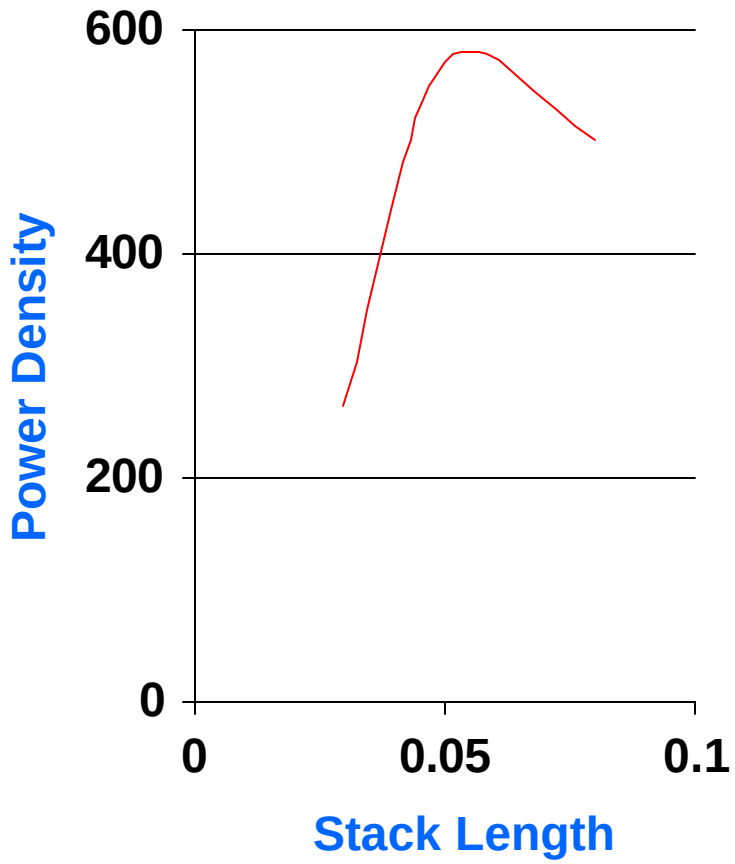


SAMPSON Rotary Motor



Scaling of Power Density

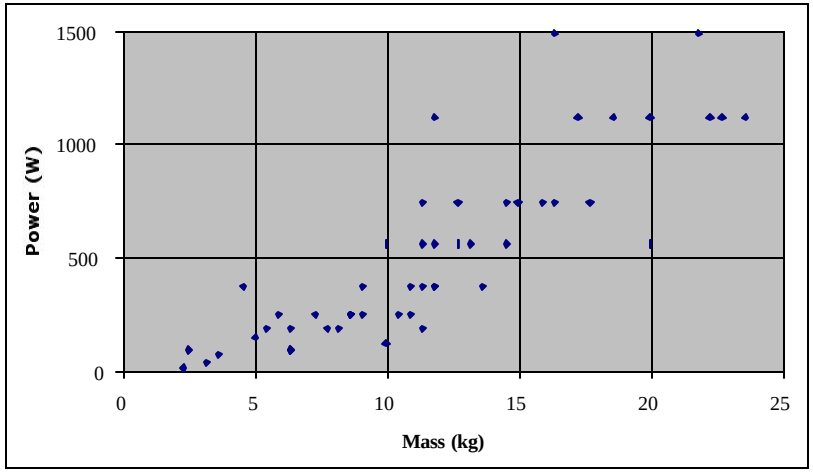
- **Optimum length scale for high power density**
  - **If too long, too massive**
  - **If too short, backlash/friction limit holding capability, speed**
  - **As short as practical to run at high step rates**
- **Reducing backlash / losses essential**
- **Fixed frequency electronics**
  - **Compact**



- **Multi-device coord for high power at load scale**

Performance Targets (pre-budget adjustment)

- **ACTUATOR = package (motor, electronics, sensor, controller)**
  - **SOA ~ 100 W/kg**
- **MOTORS**
  - **Typical AC EM:**
    - **80 W/kg (continuous)**
    - **50-80% efficiencies**
  - **Best brushless DC:**
    - **900 W/kg (continuous);**
    - **2800 W/kg (intermittent)**

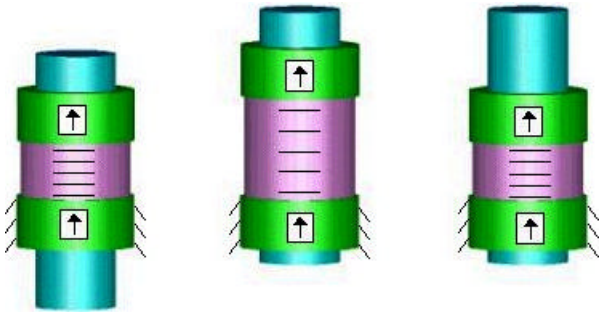


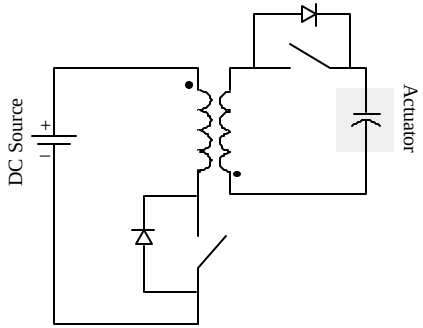
Power And Mass For Some Commercial AC Motors

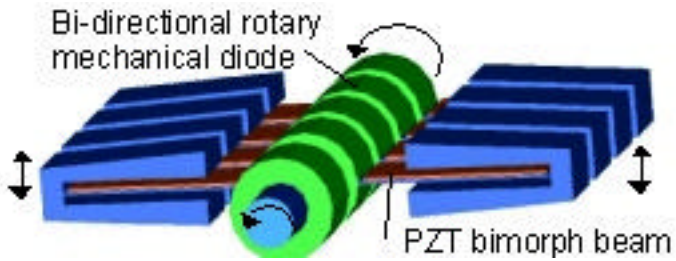
- **TARGETS**
  - **F2 ACTUATOR: 1000 W/kg; F2 MOTOR: 2000 W/kg**
  - **F1 MOTOR: 300 W/kg**
  - **F2 EFFICIENCY: Drivers: 90%; Motors: 90%**

Technical Features

- **Principle of operation**
  - **Rectification / accumulation of resonant oscillation**
    - **MECHANICAL DIODE**
- **High power density**
  - **High frequency operation (small)**
  - **Reversible diode: no transmission**
  - **Efficient power electronics**
- **Volumetric conformability**
  - **Unusual form factors**
  - **In-fin actuation**

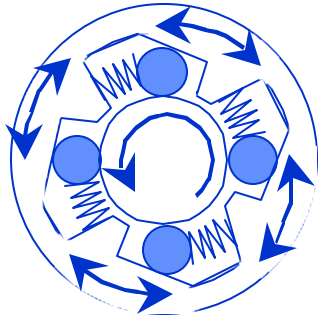






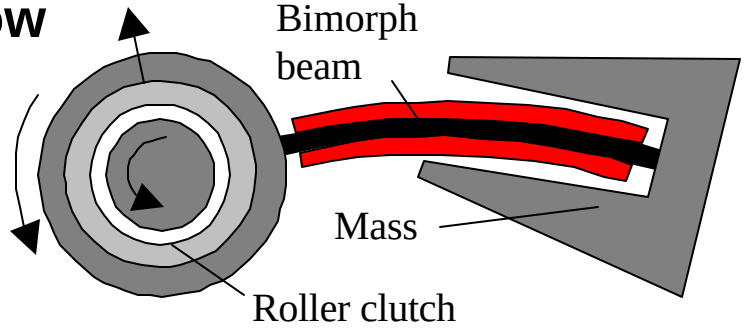
Technical Issues

- **Mechanical Diodes**
  - Reversible
  - Linear vs. rotary
  - Minimizing backlash, losses
  - Reliability

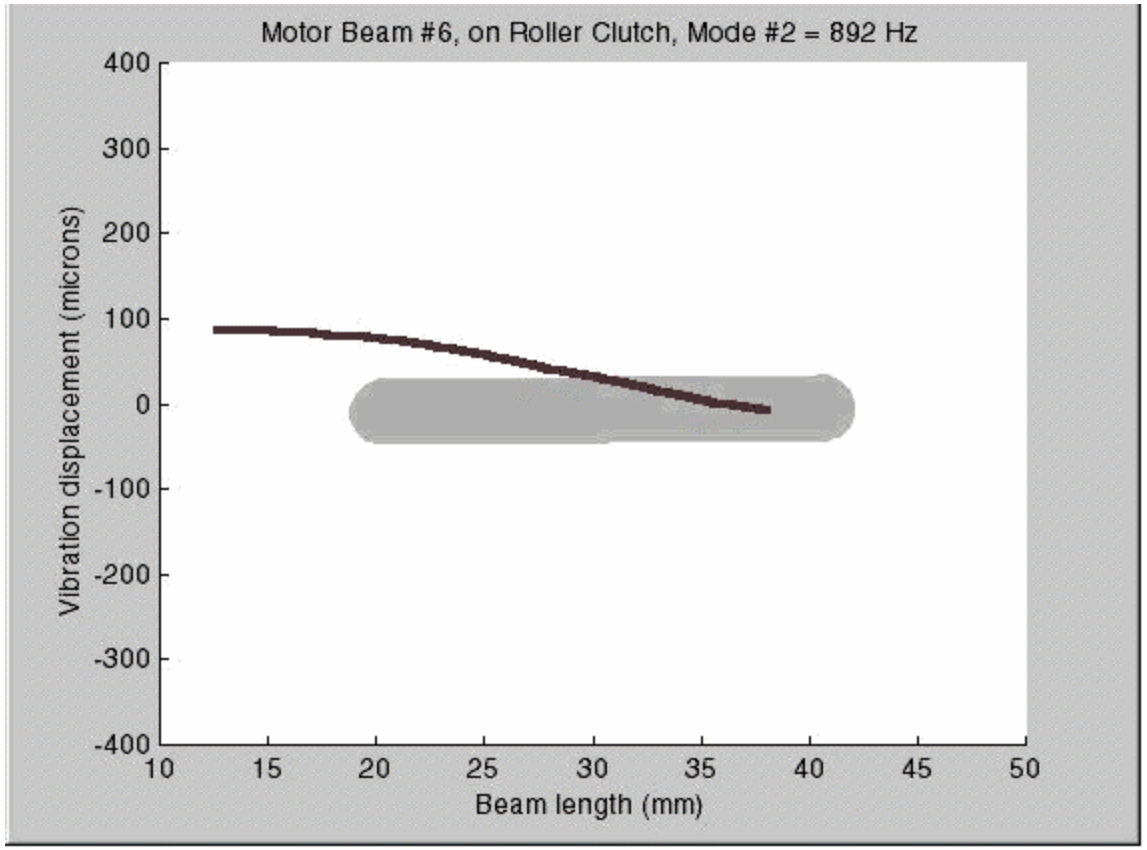


- **Power Electronics**
  - Mass, efficiency
  - Power bus step-up, power flow

- **High Frequency Oscillator**
  - Stack vs. bimorph
  - Bimorph mass, mode shape
  - Sizing and coordination (specific power vs. application)



Bimorph Drive



MEDIRRA Summary

MEchanical DIode Resonant Rectifying Actuator

- Builds on DARPA SAMPSON technology
  - High torque piezoelectric motor
- Experienced team
  - Penn State, Virginia Tech, Boeing, MPC
- Technology development
  - High specific power
    - Mechanical diode
    - Resonant drive
  - Efficient power electronics
- Technology transition
  - Aerospace actuators and applications